Nahid Zoueshtiagh/R9/USEPA/US
03/08/2006 10:37 AM

To Joseph Lapka/R9/USEPA/US@EPA
cc
bcc
Subject record - Cabrillo Port Equipment Specifications for the SCVs and the Wartsila Generator Engines

----- Forwarded by Nahid Zoueshtiagh/R9/USEPA/US on 03/08/2006 10:36 AM -----

KWright@entrix.com
06/01/2005 06:32 PM

To Nahid Zoueshtiagh/R9/USEPA/US@EPA
cc TUmenhofer@entrix.com, TRWOOD@stoel.com, jamckinsey@stoel.com
Subject Cabrillo Port Equipment Specifications for the SCVs and the Wartsila Generator Engines

Nahid:

Please find attached the following Specification documents:

For the Warsilia engines, please find attached the following specification document:

- Wartsila Specification 0047057-S504, May 13, 2005

For the SCVs, please find attached the following specification documents:

- Selas Specification, Sub-XLE, 120-180 t/hr, February 18, 2005
- COSTAIN Report No. 6407-0200-64-01-0001

As noted in my previous e-mail to you, these specification documents are referenced in the emission spreadsheets as well as the emission factor tables.

Kevin Wright
Air Resources
ENTRIX, Inc.
TEL 702-413-1020
FAX 702-413-1721


COSTAIN Report.pdf

Selas SCV Specification.pdf

Wartsila Specs 5 13 05.doc

APPENDIX 1

DETAILED DESCRIPTION KALDAIR SCV

DETAILED DESCRIPTION OF KALDAIR SCV

Kaldair has provided the following detailed description of the SCV: -

The Kaldair's "TX" Vaporiser was specifically developed in the 1970s to meet the demands of large LNG importing terminals and peak shaving installations.

The "TX" Vaporiser is an indirect-fired heat exchanger with the burner and process fluid heat exchanger contained in a single tank. Each vaporiser is supplied with full operating, safety and control instrumentation.

The standard "TX" Vaporiser is an assembly of the following major components:

1. Vaporiser Tank, which may be construction in concrete or steel
2. "TX" Burner, complete with distributor header and distribution tubes.
3. Process Tube Coil
4. Weir
5. Combustion Air Fans, Motor, Inlet and Outlet Silencer and Acoustic Housing, as required.
6. Burner Fuel Gas Controls.
7. Control System and Instrumentation.

The advantages of the Submerged Combustion "TX" Vaporiser system are:

1. Operational Safety

The process tubes are submerged in a water bath operating at temperatures of typically 30°C. This protects the tubes by ensuring that the maximum tube wall temperature can only be 30°C, even if a sudden pump trip causes loss of LNG flow.

Flame impingement or overheating and burnout of the tubes are prevented by the water bath. The exhaust gases are also cooled to the same temperature of 30°C, well below the auto-ignition temperature of the process fluid in the event of LNG leakage.

2. Proven Design

The gas industry worldwide has previously accepted the performance and reliability of the Submerged Combustion Vaporiser as being second to none. Between 100 and 200 submerged combustion units are in service. The "TX" Vaporiser has been particularly successful with installations throughout the world.

3. High Thermal Efficiency

Extremely high gross thermal efficiency, approaching 99%, can be achieved because the latent heat from the condensation of the water vapour, formed from the combustion of the hydrogen in the fuel gas, is absorbed in the water bath and transferred directly to the LNG.

4. Burner Start-Up Without Process Flow

The vaporiser can be started up and the water bath heated to its operating temperature prior to commencement of LNG flow to the process tube coil. It is possible, if required, to have the unit standing by on pilot burner only, prior to introduction of the LNG.

5. Continuation of LNG Heating on Burner Shutdown

The heat stored in the water bath continues the supply of LNG from the vaporiser, even in the event of a sudden burner shutdown, enabling a controlled shutdown of the LNG flow to be carried out.

6. No Ice Build-Up on Process Tubes

Observation of units in operation has indicated no ice build-up, even when operating at reduced loads with lower water bath temperatures. This is due to an excellent circulation of water around the tubes and the high outside film coefficient obtained by the patented submerged combustion design.

Principle of Operation

The "TX" Vaporiser uses the technique of submerged combustion. The burner combustion products are discharged directly into a water bath that is used as the heat transfer medium for heating the cryogenic fluid flowing through the stainless steel tube coil.

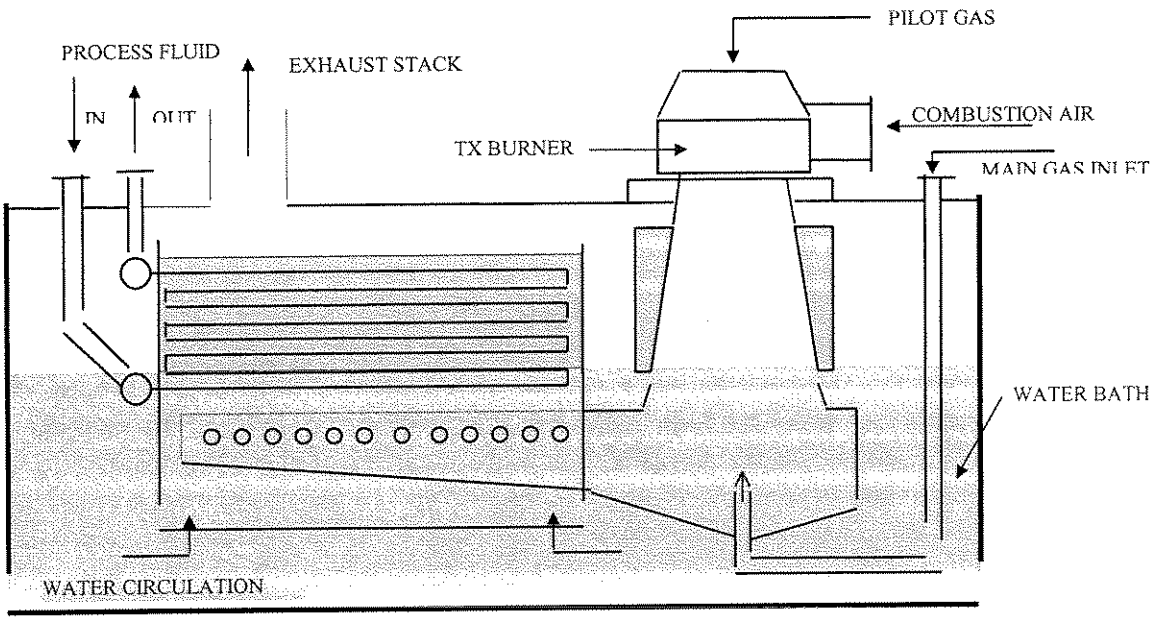
The burner used in the vaporiser is designated the "TX" burner. It is mounted at one end of the water bath so that it is partially submerged in the water, with the combustion products injected into the water below the tube bundle by a special distribution system. Injection of the combustion products forms a frothing two-phase mixture containing many small gas bubbles. The reduced density of the two-phase mixture creates a lift action that causes the mixture to rise.

This rising flow is confined within a weir assembly that surrounds the tube bundle. The froth flows up through the tube bundle and over the weir, where disengagement of the combustion product gases occurs. The water falls back over the weir and then recirculates through the heat exchanger tube bundle. It is necessary to maintain the frothing action, even at low heat duties, to maintain uniformity and to prevent icing in the tank. This is achieved in the "TX" system as a characteristic of the "TX" burner.

The heat exchanger tube coil is immersed in the water bath, within the weir space and above the burner distributor system, so that the high velocity motion of the gas/water mixture efficiently scrubs its tube surface.

The burner combustion products, after disengagement from the gas/water, are discharged to atmosphere via a carbon steel stack. Adequate disengagement space and low exhaust stack discharge velocities assure minimal carryover.

A schematic representation of the "TX" Vaporiser is shown in Figure 1.



Cross Sectional Side View

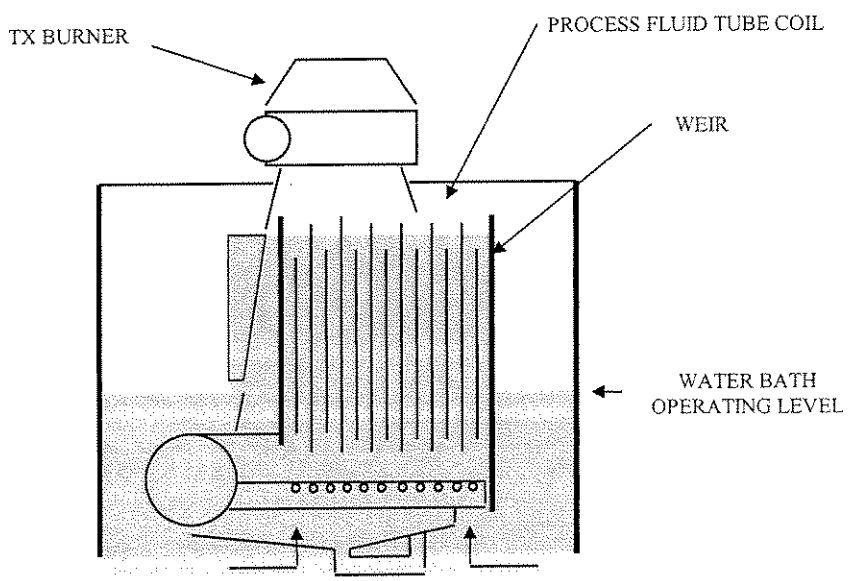


Figure 1

Vaporiser Tank

The vaporiser tank, constructed of stainless steel, houses the burner, distribution system, and process tube coil and weir assemblies.

The tank is an enclosed design, with removable deck plates permitting ready access to the vaporiser internals. Two deck-sited access hatches are provided as standard for routine access.

The main tank nozzles for connection are:

- Exhaust gas discharge to stack
- Water overflow
- Tank drain
- Tank water fill line
- Gas and air feed connection to the main burner

"TX" Burner

The "TX" burner employed has been specially developed as an integral part of the submerged combustion heater design. It is of an all-metal construction and comprises an upper volute air register and lower volute distributor, connected by a central conical section. The main combustion air is fed tangentially into the upper volute, which is equipped with the pilot, ignition and flame detection systems. The main gas burner injection and secondary air mixer are fitted in the lower volute, firing upwards into the central conical section, where proper combustion takes place.

Approximately 20% of the total combustion air is supplied through the primary air mixer. Excellent combustion characteristics are achieved due to the downward vortex motion of the combustion air and its subsequent recirculation in the reverse direction along the burner axis.

No refractory material is required in the burner, as the downward vortex motion of the main combustion air, created by the tangential entry passing in a spiral path around the periphery of the combustion section, keeps the metal skin cool.

In addition, immersion of the whole of the lower distributor and the major part of the conical section of the burner in the water bath enables a burner skin temperature of approximately 95°C to be maintained. The exposed section of the burner cone is cooled by a constantly overflowing water jacket.

The "TX" burner is schematically represented below in Figure - 2.

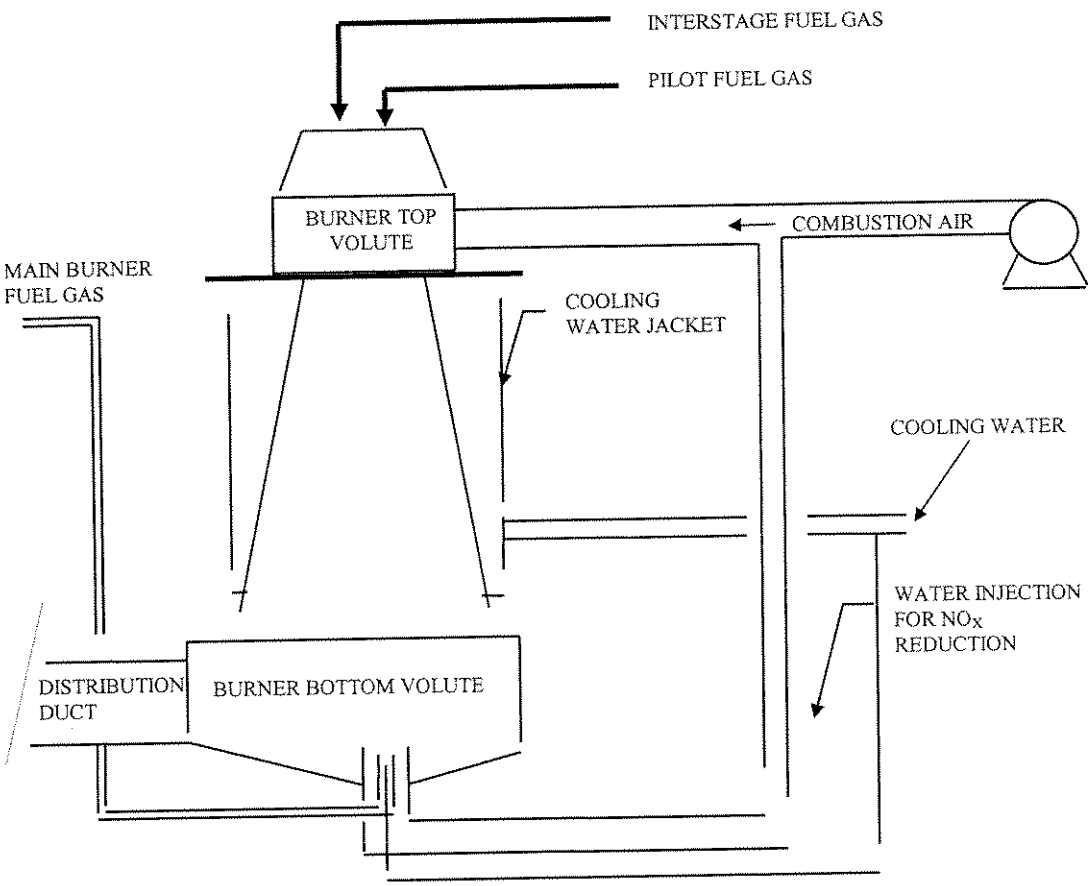


Figure 2 - Schematic View of TX Burner

The advantages of the "TX" burner that make it particularly suitable for submerged combustion applications, are:

A. All-Metal Burner Construction

The complete absence of refractory lining enables large combustion chambers of relatively lightweight construction to be built. Problems normally encountered with refractory spalling and slower response characteristics are eliminated. It is also possible to fully immerse the burner combustion chamber in water.

B. Low Combustion Chamber Metal Temperature

Special burner design and immersion in the water bath enables a burner skin temperature as low as 95°C to be maintained. With temperatures within this range, corrosion effects are negligible.

C. Simple Pilot Burner

The simple raw gas pilot and primary burner system employed enables repetitive ignition of a range of hydrocarbon fuel gases. The need for an accurately adjusted air/fuel ratio, required for pre-mix gas pilots with their inherent reliability problems, is eliminated. The problem of damp spark igniters, caused by operation above the water bath, is overcome by fitting a high-energy ignition system.

D. High Operational Reliability

The "TX" burner requires no moving parts and no refractory, giving improved long-term reliability.

E. High Turndown

The special design of the "TX" burner enables higher turndowns to be achieved, than was previously possible with earlier designs, without the need for on/off controls. The burner turndown of 10 to 1 is well above normal process turndown requirements for vaporiser operation.

F. Simplicity of Burner Controls

The single burner permits rigid adherence to National Standards and Codes of Practice, yet still retains a simple control scheme.

G. Flexibility of Burner Air/Fuel Ratio

The stability of the burner over a very wide range of air/fuel ratios ensures reliability of operation and ease of commissioning. The burner is especially tolerant of fuels with varying calorific values.

H. Low NOx Level

The excellent combustion characteristics of the novel, all metal "TX" burner offer significantly lower NOx levels than traditional refractory lined, nozzle mix burners usually employed in this type of application. This is due to the progressive mixing and combustion that occurs in the central cone of the burner (see Figure 2).

I. Quiet Operation

Firing the "TX" burner in a submerged combustion application, adds considerably to quiet operation due to the complete submergence of its exhaust in water.

Process Tube Coil

The process tube coil is a multi-tube serpentine tube bundle mounted horizontally within the weir. The process fluid flows from the bottom header up through the tubes to the top exit header. The inlet and exit pipework is taken above the vaporiser decking for final connection on site. Connecting flanges are arranged just above the vaporiser deck plates.

Distribution System

The distribution header and sparge tube system transports the hot products of combustion from the burner and distributes them directly into the water bath below the process tube coil and within the weir space. It is designed to give uniform distribution of the froth around the tube bundle and to maintain the frothing action throughout the range of turndown.

The distribution system is bolted to support pads in the tank base, with further location points within the weir frame.

Weir and Tube Coil Supports

The weir completely surrounds the process tube coil on four sides, remaining open at top and bottom. Its function is to confine the lift action created by the discharge of combustion gases into the water bath immediately below the tube coil and within the weir space.

The main weir supports, bolted to pads on the tank floor, also provide bracing for the tube coil hangers.

Once the deck plates have been removed for access, the tube coil and weir assembly may be removed as a complete package, if required.

The lower section of the weir straddles, and is fastened to the burner distribution system.

Exhaust Stack

The exhaust stack is manufactured from epoxy-coated carbon steel. Exhaust stack discharge velocity at design conditions is typically 6-8 metres/sec.

The mechanical design provides disengagement space above the burner tube bundle assembly, so that carryover is minimized. Entrainment of water from the bath is further limited with the inclusion in the design of a demister pad.

Combustion Products

Mass Flowrate	Molar Flowrate	Volumetric Flowrate			
(kg/h)	(kg/kmol)	Sm^3/h	Nm^3/h	Sft^3/h	Nft^3/h
46,025	29.835	36,470	34,570	1,287,923	1,220,844

Stack Gas Analysis "Dry Basis"

Combustion Products	Mol% of Flue Gas
Oxygen O_2	3.6
Nitrogen N_2	85.5
Carbon Dioxide CO_2	9.8

NO_X	40/50 ppm	Current standard
	30/35 ppm	Under test likely to be available within 12 months
CO	100 ppm	Maximum

NO_X and CO referred to 3% O_2 @ duty point.

Discharge Water Analysis

The over flow water, produced from combustion will be continuously discharged while the unit is in operation. This water will be dosed with NaHCO3 to keep the pH within the range pH 6 to 9. In no circumstances should the chloride content of the feed water exceed 50ppm this limit is set to minimise the risk of corrosion to the stainless steel components within the water bath.

The overflow water composition is as follows: -

Nitrate	5mg/l
Sulphates	Maximum as per the feed water Minimum tending to zero as the water is diluted by the water generated from the combustion process.
Sodium	50mg/l
Total dissolved Solids	Will depend on the feed water but due to dilution by the water generated from the combustion process will fall to a minimum. Typical measured value 485mg/l

Combustion Air Fan and Controls

The "TX" Vaporiser is fitted with a single 100% duty forced draught centrifugal combustion air fan.

The fan is fitted with a pneumatically actuated inlet vane control.

These are controlled by the natural gas outlet temperature controller and work in combination with the fuel gas control valve to control the firing rate of the vaporiser.

Fuel Gas Controls

The fuel gas controls are divided into three sections:

1. Main Gas

This line controls the fuel gas supply to the main burner through a set of double block and vent valves. A control valve is installed down stream of the block valves. The line is also fitted with

pressure regulator, a flow transmitter, pressure transmitter and manual isolation valves at each end of the line. The control valve and double block and vent valves are fitted with position monitoring switches.

2. Interstage Gas

This line controls the fuel gas to the interstage burner through another set of double block and vent valves, and is taken from the main gas line upstream of the main gas double block and vent valves. A fixed orifice controls the gas flow. A non-return valve is installed close to the burner. Pressure is monitored by local pressure gauges.

3. Pilot Gas

This line controls the fuel gas to the pilot burner through a solenoid valve and is taken from the interstage gas line by opening the first interstage block valve. A fixed orifice controls the gas flow and a non-return valve is installed close to the burner. Pressure is monitored by a local pressure gauge.

Control Panel and Instrumentation

The "TX" Vaporiser is designed as a completely self-contained unit with all necessary controls housed in a local control panel that is mounted adjacent to the vaporiser tank.

The panel is for use in a hazardous area, and is a certified pressurized enclosure.

A PLC unit installed in the panel controls the vaporiser.

An operator interface terminal is installed on the front of the local panel, all alarm functions are displayed on the screen and all control functions are operated from the keypad of this terminal.

The vaporiser is controlled automatically from the local panel. The local panel controls the start up burner, combustion air fan and cooling water pump. The output of the main burner is controlled by monitoring the natural gas outlet temperature, the temperature controller function in the PLC then modulates the main burner output.

The panel will be designed for an outdoor Zone 1, Group IIB, T3 area location and will use an Ex(p) type air purged enclosure, in accordance with EN 50016.

The "TX" Vaporiser control system is installed in a pressurized enclosure located adjacent to the vaporiser. All controls for normal operation are located on the panel front. The system can also be started remotely from the Client's control room.

The control system performs the following functions:

1. Burner start-up and shutdown
2. Monitoring of the "TX" burner during operation

3. Natural gas outlet temperature control

The control system includes all safety interlocks for safe operation. All process parameters are continuously monitored and in the event of a fault condition, the "TX" Vaporiser is shutdown. To give advance warning of a fault condition, alarms are also provided.

Operation

The control system can be started at the local panel or remotely from the Client's control room. For normal operation, start-up is by means of a single push button and the start sequence is then controlled fully automatically. For maintenance and commissioning there is the facility to start-up manually and hold the start-up sequence at the intermediate stages. The Natural Gas temperature controller is operated from the front of the local panel. This can be operated manually for maintenance and automatically for normal operation. The set point can be adjusted from the front of the panel. The controller has three output channels, one to each control valve. The actual signal level of each channel is set on commissioning to give the optimum air/fuel gas ratio.

1 Alarms and Shutdown

The "TX" control system has three levels of safety interlocks.

2 Shutdown (SD)

When a fault condition is detected the "TX" burner is shutdown and the signal to the main control to open the LNG inlet valves is removed.

3 LNG Permissive

When a fault is detected the burner continues to operate, but the signal to the main control room to open the LNG inlet valves is removed.

4 Alarms

A visual and audible alarm is given, but the "TX" burner continues to operate.

Automatic shutdown of the vaporiser results from the failure of any of the following trips:

- Combustion Air Pressure
- Low Fuel Gas Pressure
- High Fuel Gas Pressure
- High Stack Gas Temperature
- High Water Bath Temperature
- Flame Failure on the "TX" Burner
- Low Water Level
- Cooling Pump Water Failure
- Low LNG Outlet Temperature

Alarms are provided on the following:

- Stack Gas Temperature High
- Water Bath Temperature High
- Water Bath Temperature Low
- Water Level Low
- Instrument Air Pressure Low
- Water Bath pH Low

Signals to Client

- Common Shutdown
- Common Alarm
- Shutdown of LNG on Low Water Bath Temperature (LNG Permissive)

Signals from Client:

- Emergency Shutdown

"TX" Burner Ignition

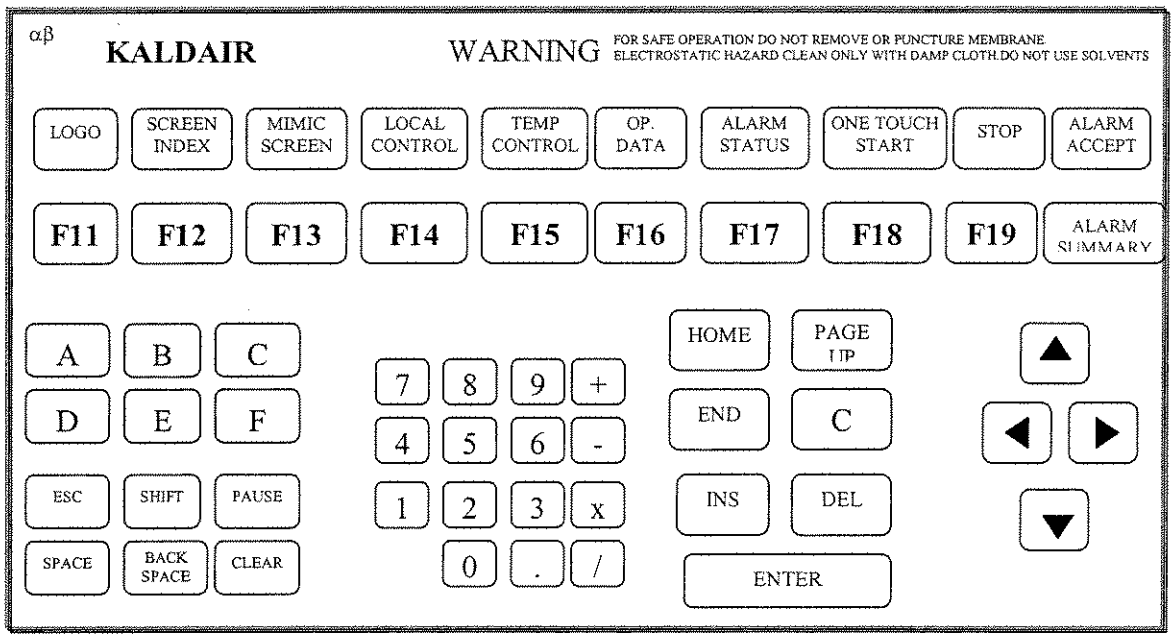
The "TX" Burner is fitted with a high energy, ignition system that overcomes the difficulty of ignition above a water bath. The igniter is energised automatically during the start sequence and the flame continually monitored, from pilot burner through to main burner, by a certified UV flame detector.

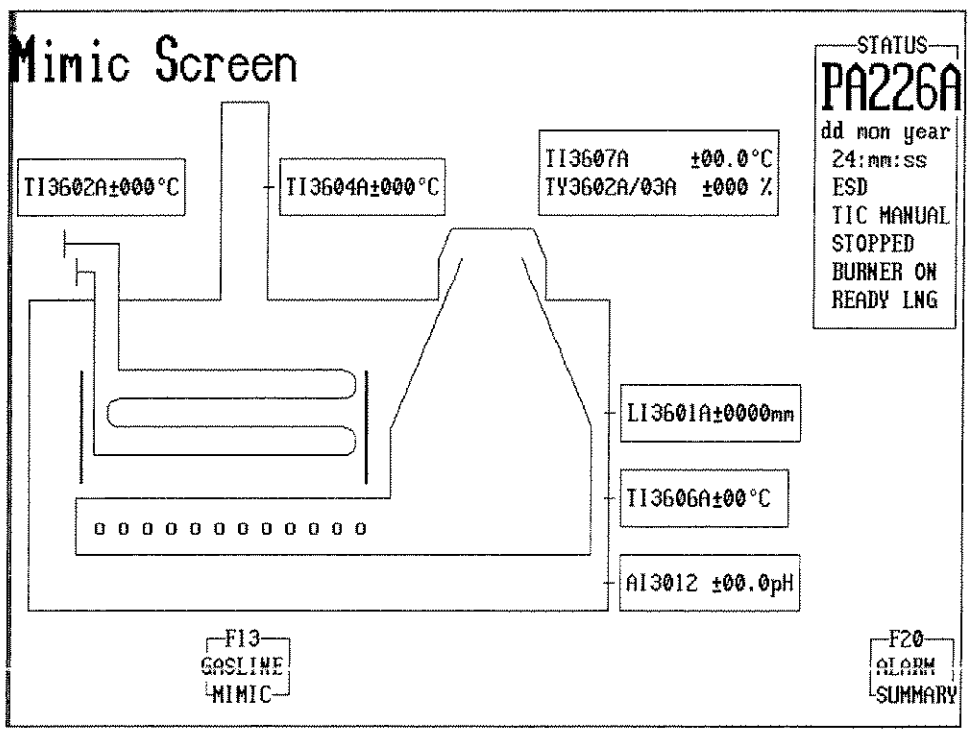
The ignition logic ensures automatic shutdown in the event of:

1. Pilot burner not ignited and established within permitted time.
2. Main flame not established within permitted time.
3. Loss of flame.

Operator Interface Terminal

With the exception of local/remote operation select, emergency stop and system reset, all operation and control functions are controlled from the operator interface terminal. The list of functions can be displayed using the "screen index" key. The layout of the terminal keypad is shown below. The top row of keys will perform the functions shown at any time and do not depend on the screen display. The lower keys (F11 to F19) have functions that change according to the screen display these functions are shown at the bottom of each screen. A typical example of a screen display is shown on the next page.





Typical Procedures for Installation and Maintenance

Each vaporiser unit is finished and trial-assembled before shipment with the exception of the combustion air fans and silencing equipment.

The combustion pipework, consisting of the pilot gas, primary burner and main burner controls, are pre-piped and tested prior to dispatch from the workshop. The termination point is a single fire-safe isolation valve.

The water pipework consists of a main isolation valve, the termination point, a fill valve and solenoid valve to control the tank level.

The combustion air fan and associated silencing equipment will be supplied separately for installation adjacent to the unit. The combustion air ducting to connect the fan to the burner will also be shipped separately. A flexible joint is supplied as the final anti-vibration mounting.

Site assembly of the unit typically consists of:

- Vaporiser internals are pre-erected into the stainless steel tank.
- Off-loading and fixing the combustion air blower and motor package and erection of the acoustic housing, if fitted.
- Fitting the combustion air-ductwork.
- Connecting process service lines.
- Electric hook-ups to panel, combustion air fan and water pump motors.
- Pneumatic hook-ups to panel and local connections.
- Connection of water fill pipework

Maintenance

3 Months - 1500 hours

1. Inspect the flame scanner lens to ensure freedom from cracks, dirt and moisture. Clean or replace as required.
2. Remove and inspect igniter system. Check HE igniter for wear and replace if necessary.
3. Visually inspect the entire external system for signs of leakage, wear, overheating and general damage.
4. Check calibration of pneumatic control equipment.
5. Inspect valves to ensure freedom of operation and lubricate where necessary.

Annually - 6000 hours

1. Remove and renew scanner cell.
2. Clean, re-calibrate and check function of all safety interlock devices.
3. Visually inspect the tank internals for signs of leakage, wear, overheating and general damage.

4. Maintenance of ancillary control equipment should be carried out in accordance with manufacturers' recommendations.

Special Tools

No special tools are required for maintenance.

Performance Data and Dimensions

1. pH Dosing

Dosing Medium	$NaHCO_3$ Saturated	$NaOH_{32}$ % Solution	Na_2CO_3 12%
Solution consumption @ max duty	118.54 l/h	15.15 l/h	40.43 l/h
Required storage volume for:			
24 hrs operation	$2.85m^3$	$0.36m^3$	$0.97m^3$
7 days operation	$19.92m^3$	$2.55m^3$	$6.79m^3$

2. Tube bundle Volume: 3.2 m^3

3. Weights

Description	Weight (kg)	Dimensions (mm)			Volume
		L	W	H	
Exhaust Stack	3000	7200	2400	2400	41
Tank Assembly	78000	13,000	4100	4000	213
Control Panel	1400	2000	2500	2000	10
Fan and Motor	1700	2300	1600	2600	10
Ducting Sections	2500	4300	2500	1400	15
Inlet Silencer	500	4400	1900	1400	12
Ducting Sections	400	3500	1900	1800	12
Acoustic Enclosure	1600	4900	2000	1400	14
Total weight	89,100kg			Total Vol	$326.7m^3$

For operating weight add: 117,000kg

4. Noise Data.

Please see the following typical noise measurements.

dBA	63	125	250	500	1k	2k	4k	8k
85	85	92	78	81	81	77	75	74

5. Stack Gas Emissions for a 173 Tonnes per unit.

CO_2 = 6,123 kg/h @173,000 kg/h of LNG Flow rate

N0x 30 ppmv (3% O2) max at full duty

CO 50 ppmv Max

VOC 4.1 ppmv(3% O2)

Particulates 0.005 lb/MMBtu(HHV)

SELAS FLUID PROCESSING CORP.	DATE: 2/18/05	PAGE 1 OF 3
BLUE BELL, PA	DOC NO:	
	SFPC PROJ. NO.: 04122V	
VAPORIZER DATA SHEET	ISSUE: B (Proposal)	BY: CDS
	ISSUE:	CHECK:

PURCHASER / OWNER:	BHP Billiton	**ITEM NO. :**	F101A to F101F	
SERVICE:	Vaporize LNG	**LOCATION:**	Outdoor, Floating Platform	REV.
MODEL:	Sub-X 120-180 t/hr Low Emissions	DRY WT., lb:		
NO. REQUIRED:	8			
TYPE:	Submerged Combustion	NO. BURNERS:	1 per unit	

PROCESS DESIGN CONDITIONS

CASE	Scarborough					
	(Design Basis)					
AMBIENT CONDITIONS						
TEMPERATURE, °F	60					
PRESSURE, PSI	14.7					
RELATIVE HUMIDITY	60%					
LNG DESCRIPTION						
CH_4 MOLE %	99.68%					
C_2H_6 MOLE %	0.11%					
C_3H_8 MOLE %	0.00%					
C_4H_{10} MOLE %	0.00%					
C_5H_{12} MOLE %	0.00%					
N_2 MOLE %	0.20%					
MW	16.1					
VAPORIZATION RATE, MM SCFD	202.8					
VAPORIZATION RATE, LB/HR	357,899	162.3 t/hr				
LNG INLET TEMPERATURE, °F	-258	-161°C				
NG OUTLET TEMPERATURE, °F	41	5°C				
NG OUTLET PRESSURE, PSIG	1,400	96.5 bar g				
DUTY, MM BTU/HR	112.7	33.0 MW				
VAPORIZER SEND OUT RATE, MM SCFD	221.9	177.6 t/hr	see note 5			
FUEL DESCRIPTION						
CH_4 MOLE %	98.06%					
C_2H_6 MOLE %	0.06%					
C_3H_8 MOLE %	0.00%					
C_4H_{10} MOLE %	0.00%					
C_5H_{12} MOLE %	0.00%					
N_2 MOLE %	1.87%					
HEATING VALUE (HHV), BTU/SCF	990					
HEATING VALUE (HHV), BTU/LB	23,105					
FUEL INLET TEMPERATURE, °F	60					
FUEL OUTLET TEMPERATURE, °F	N/A					
FUEL OUTLET PRESSURE, PSIG	N/A					
CALCULATED VALUES						
WATER OVERFLOW RATE, GPM	17.1					
FUEL RATE, SCFH	116,087					
PROCESS PRESSURE DROP, PSI	50.0					
PROCESS INLET PRESSURE, PSIG	1,450					
EFFICIENCY (HHV)	98%					
BATH TEMPERATURE, °F	83					
FUEL PRESSURE DROP, PSI	N/A					
FLUE GAS						
CO_2 MOLE %	6.6%					
N_2 MOLE %	81.5%					
O_2 MOLE %	8.0%					
H_2O MOLE %	3.9%					
FLOW RATE, SCFM	28,605					
TEMPERATURE, °F	83					

SELAS FLUID PROCESSING CORP. BLUE BELL, PA VAPORIZER DATA SHEET	DATE: 2/18/05 PAGE 2 OF 3 DOC NO: SFPC PROJ. NO.: 04122V ISSUE: B (Proposal) BY: CDS ISSUE: CHECK:

TUBE BUNDLE DETAILS

	Process Bundle		Fuel Pre-heat Bundle		REV.
INLET HEADER CONNECTION	304/304L SS	8" 900# Flange			
OUTLET HEADER CONNECTION	304/304L SS	12" 900# Flange			
TUBES	304/304L SS	1.125" OD, 0,083" Avg Wall			
PASSES	8				
HEAT TRANSFER AREA, FT^2	3864				
DESIGN PRESSURE, PSIG	2030	(Design Basis)			
DESIGN TEMPERATURE, min/max, ^oF	-320 / +150				
DESIGN CODE	ASME SECTION VIII (Stamped), T-Thermal Spec. 211A		ASME SECTION VIII (Stamped), T-Thermal Spec. 211A		

TANK DETAILS

TANK	MATERIAL:	Stainless Steel
LENGTH	40' -0" (INSIDE TANK WALL)	
WIDTH	16'-0" (INSIDE TANK WALL)	
HEIGHT	12' (FLOOR TO BOTTOM TANK TOP)	
DOWNCOMER/DISTRIBUTOR:	MATERIAL:	304 SS
WEIR:	MATERIAL:	304 SS
COVER PLATE:	MATERIAL:	304 SS
DEMISTER:		
CONNECTIONS		
DRAIN	6" 150# RF FLANGE (BY PURCHASER)	
OVERFLOW	3" 150# RF FLANGE (BY PURCHASER)	

OTHER CONNECTIONS

FUEL	4" 150# RF FLANGE
INSTRUMENT AIR	1" 150# RF FLANGE
WATER	3" 150# RF FLANGE

STACK

DIAMETER	4'-9" ID
HEIGHT	TBD
MATERIAL	CARBON STEEL
LOCATION	TBD

CONNECTIONS	SIZE	TYPE	QUANTITY
TEMP SWITCHES	3/4"	3000# COUPLING	1
TEMP ELEMENTS	3/4"	3000# COUPLING	1
COMUSTIBLE ANALYZER	4"	150# FLANGE	1
EPA TEST PORTS	2"	150# FLANGE	2

LINE DESCRIPTIONS

LINE	**SIZE**	**MATERIAL**
COMBUSTION AIR MAIN	24"	CARBON STEEL
COMBUSTION AIR PRIMARY	12"	CARBON STEEL
COMBUSTION AIR SECONDARY	24"	CARBON STEEL
FUEL MAIN	4"	CARBON STEEL
FUEL - 1^{st} STAGE	3/4"	CARBON STEEL
FUEL - 2^{nd} STAGE	1"	CARBON STEEL
WATER - PUMP INLET	3"	STAINLESS STEEL
WATER - PUMP OUTLET	2"	STAINLESS STEEL
WATER - BURNER JACKET	2"	STAINLESS STEEL
WATER - AIR NOZZLE	1"	STAINLESS STEEL
WATER - NO_X REDUCTION	1"	STAINLESS STEEL

SELAS FLUID PROCESSING CORP. BLUE BELL, PA VAPORIZER DATA SHEET	DATE: 2/18/05 PAGE 3 OF 3 DOC NO: SFPC PROJ. NO.: 04122V ISSUE: B (Proposal) BY: CDS ISSUE: CHECK:

GUARANTEES

REV.

CONDITION					
AMBIENT CONDITIONS					
TEMPERATURE, °F					
PRESSURE, PSI					
RELATIVE HUMIDITY					
LNG DESCRIPTION					
CH_4 MOLE %					
C_2H_6 MOLE %					
C_3H_8 MOLE %					
C_4H_{10} MOLE %					
C_5H_{12} MOLE %					
N_2 MOLE %					
VAPORIZATION RATE, MM SCFD					
VAPORIZATION RATE, LB/HR					
LNG INLET TEMPERATURE, °F					
NG OUTLET TEMPERATURE, °F					
NG OUTLET PRESSURE, PSIG					
VAPORIZER SEND OUT RATE, MM SCFD					
FUEL DESCRIPTION					
CH_4 MOLE %					
C_2H_6 MOLE %					
C_3H_8 MOLE %					
C_4H_{10} MOLE %					
C_5H_{12} MOLE %					
N_2 MOLE %					
GUARANTEES					
PRESSURE DROP, PSI	< 50				
EFFICIENCY (HHV)	> 98%				
NO_x CONCENTRATION	< 20	ppmvd as NO_2 (corrected to 3% O_2)			
CO CONCENTRATION	< 100	ppmvd (corrected to 3% O_2)			

NOTES

1) Efficiency (HHV) is defined as:

Heat Transferred: 357,899 lb/hr * 315 Btu/lb = 112.7 MM Btu/hr = 98.0%

Fuel Firing Rate: 48107 lb/hr * 23,105 Btu/lb = 115.0 MM Btu/hr

2) Comparison of Calculated (Design) Values and Guaranteed Values (at the basis of 60°F, 60% RH ambient conditions)

		Calculated Value	Guaranteed Value
HHV Efficiency	%		
Send Out Rate	MM SCFD		
Pressure Drop	PSI		

3) At lower operating pressures, the calculated heat duty would be greater. Therefore, the expected vaporization rate shall be reduced.

4) For an LNG with lower methane content, the calculated duty would be greater. Therefore, the expected vaporization rate shall be reduced.

5) Vaporizer send out rate is defined as the vaporization rate minus the fuel consumed by the vaporizer burner(s).

6) The above values are based on a high excess air burner.

SPECIFICATION
NO. 00470507-S504

Project: Cabrillo port LNG FSRU
Customer: BHP Billiton

DATE

13 MAY 2005

REVISION
1

OUR CONTACT PERSONS
Alexander Eykerman / Rex O'Connor

WÄRTSILÄ

CONTENTS

1. GENERAL DESCRIPTION

1.1 BACKGROUND

This specification describes the Wärtsilä scope of supply of main power plant offered for the BHP Billiton LNG FSRU. The LNG FSRU will be located off California coast.

1.2 DESCRIPTION OF THE POWER PLANT

The power plant consists of four (4) Wärtsilä 9L50DF generating sets. The engines are divided into two separate engine rooms. The machinery listed below will meet the classification requirements of DNV (or other major class society to be agreed) in force at the date of quotation.

1.3 OPERATING AND REDUNDANCY PHILOSOPHY

The generating sets are primarily operated using gas fuel. Light fuel oil (LFO) is used as pilot fuel, i.e. for ignition in the Wärtsilä dual fuel (DF) engines.

LFO is also used as backup fuel in the generating sets. In case of trouble in gas fuel supply, the generating sets will automatically switch into LFO operation and can give their full output also using LFO.

Generating sets are recommended to be at minimum arranged in two compartments to offer redundancy in case of fire, gas leak or flooding. Some auxiliary system components are also arranged to serve all generating sets in an engine room.

2. GENERATING SETS

2.1 GENSET ENGINE, WÄRTSILÄ 9L50DF

4

2.1.1 Classification

The engine and equipment listed below will meet the classification requirements of DNV in force at the date of quotation. Certificates will be submitted according to the classification requirements.

2.1.2 Technical data

The genset engines, as well as alternator and all genset auxiliary equipment, are designed for the following ambient conditions:

Maximum ambient air temperature	45 °C
Minimum ambient air temperature	5 °C
Maximum sum of pressure drop in inlet and exhaust	5 kPa
Maximum relative humidity	60 %
Max. LT cooling water inlet temperature	35 °C

2.1.2.1 Technical particulars

Engine designation	9L50DF
Number of cylinders	9
Cylinder configuration	In-line
Cylinder bore	500 mm
Cylinder stroke	580 mm
Swept volume	113,9 dm^3/cyl
Engine speed	514 rpm
Maximum continuous rating (MCR)	8550 kW_m
Mean piston speed	9,9 m/s @ 514 rpm
BMEP at MCR	20,0 bar
Direction of rotation	Clockwise

The power stated is valid at above conditions in accordance with ISO 3046-1.

The standard engine complies with the maximum permissible NO_X emission according to MARPOL 73/78 ANNEX VI.

The engine will be tested in our workshop in accordance with the requirements of the classification society and our own standard based on the maximum continuous rated power stated above. After test run the fuel rack position will be limited to 100 per cent power. Fuel to be used is our standard marine diesel fuel.

2.1.2.2 Specific energy consumption

Gas fuel operation:

Specific fuel gas consumption at 100 % load (MCR) with engine driven pumps 7590 kJ/kWh, tolerance ± 5 %.

Specific fuel oil consumption at 100 % load (MCR) with engine driven pumps 1,0 g/kWh, tolerance ± 5 %. .

Diesel fuel operation:

Specific fuel oil consumption at 100 % load (MCR) with engine driven pumps 189 g/kWh, tolerance ± 5 %. .

The above values are based on a lower calorific value of fuel oil at least 42,700 kJ/kg and according to ISO 3046-1. The requirements for fuel quality as given below.

2.1.2.3 Fuel oil specification

The engine accepts without any load limitation fuel according to ISO 8217:1996 (E), ISO-F-DMX, ISO-F-DMA, and ISO-F-DMB. The fuel also has to meet the following requirements (maximum/minimum values):

Property	Unit	ISO-F-DMB	Test method ref.
Viscosity, min., before injection pumps [1)]	cSt	2,8	ISO 3104
Viscosity, max.	cSt at 40°C	11	ISO 3104
Viscosity, max, before injection pumps [1)]	cSt	24	ISO 3104
Density, max.	kg/m³ at 15°C	900	ISO 3675 or 12185
Cetane number, min.		35	ISO 5165 or 4264
Water, max.	% volume	0,3	ISO 3733
Sulphur, max.	% mass	2	ISO 8754
Ash, max.	% mass	0,01	ISO 6245
Carbon residue (micro method, 10 % vol dist. bottoms), max.	% mass	—	ISO 10370
Carbon residue (micro method), max.	% mass	0,30	ISO 10370
Sediment, max.	% mass	0,07	ISO 3735
Flash point (PMCC), min. [1)]	°C	60	ISO 2719
Pour point, max. [2)]	°C	0–6	ISO 3016

1) Additional properties specified by the engine manufacturer, which are not included in the ISO specification or differ from the ISO specification.

2) Different limits specified for winter and summer qualities.

2.1.2.4 Fuel gas specification

The engine is designed for continuous operation, without reduction in rated output, on natural gas with the following properties

Methane	99.68180%
Ethane	0.11240%
Propane	0.00060%
n-Butane	0.00110%
i-Butane	0.00110%
n-Pentane	0.00060%
Isopentane	0.00060%
C6	0.00080%
C7	0.00150%
C8	0.00000%
N2	0.19390%
CO2	0.00560%
H2O	0.00000%
H2S	5 ppm

With following maximum / minimum values content of gas at engine inlet:

Lower heating value, min. [1]	28 MJ/Nm^3 [2]
Gas methane number, min	80 [3]
Methane content, min	70 vol-%
Hydrogen sulphide, max	0,05 vol-%
Hydrogen, max	3 vol-%
Ammonia, max	25 mg/Nm^3
Chlorine + Fluorines, max	50 mg/Nm^3
Particles or solid content, max	50 mg/Nm^3
Particles or solids, size	5 µm
Gas inlet temperature	0 – 50 °C

[1] The required gas feed pressure is dependent on the LHV

[2] Values given at Nm^3 are at 0 °C and 101,3kPa.

Lubricating oil consumption

Specific lubricating oil consumption at maximum continuous rated power is 0.5 g/kWh, tolerance 0.2 g/kWh.

The lubricating oil used is to be according to Wärtsilä recommendation.

2.1.3 Built-on fuel system

The engine is designed for continuous operation with natural gas with a small amount (about 1%) of light fuel oil (LFO) as pilot fuel, but can also be run entirely on LFO.

Dual fuel gas and oil system consists of:

Ported gas admission with electronically controlled valves in the inlet duct of each cylinder

Low pressure gas pipes made of steel including a common rail and individual feed pipes for each cylinder

Low pressure LFO supply pipes

High pressure LFO injection pipes, double wall with common leak alarm

LFO injection pump, individual for each cylinder head

Twin fuel injector in each cylinder head (Combined main fuel oil and pilot fuel injection valve) allowing full load capability on LFO and providing electronically controlled pilot fuel injection

Engine driven pilot fuel high pressure pump, common for all cylinders (common rail)

2.1.4 Built-on lubricating oil system

Built-on lubricating oil system consists of:

By-pass filter of centrifugal type

Oil sump of wet type

Engine driven lubricating oil pump of screw type, with built-in pressure control valve

2.1.5 Built-on starting system

The Wärtsilä 50DF engine is started by injection of starting air into cylinders.

Built-on starting air system consists of:

Pneumatically operated 30 bar main starting air valve (electronically controlled)

Non-return valve

Flame arrestor

Starting air distributor

Pipes made of steel

Starting air valve in each cylinder head

Slow turning device

Starting block switch when electrical turning device engaged

Built-on starting air system also delivers working media for electro-pneumatic over speed trip device.

2.1.6 Built-on control air system

The internal control air system is used as working media for turbocharger waste gate, oil mist detector and turbocharger compressor cleaning device.

2.1.7 Built-on cooling water system

Built-on high temperature (HT) cooling water system consists of:

Water pipes of steel from engine

Engine driven centrifugal HT-pump

Pipe connection for jacket water preheater

HT charge air cooler

Built-on low temperature (LT) cooling water system consists of:

Water pipes of steel from engine

Engine driven centrifugal LT-pump

Pipe connections for alternator cooling water circulating pump

LT charge air cooler

2.1.8 Built-on exhaust gas and charge air system

Exhaust manifold with flexibly mounted insulation box

Turbocharger

Exhaust gas waste gate for adjusting the air-fuel ratio (by-passing the exhaust gases past the turbocharger).

2.1.9 Built-on control and monitoring system

The Wärtsilä Engine Control System (WECS 8000) controls the engine itself and interfaces to the Unit Control Panel (UCP).

The WECS 8000 for DF engines is a physically distributed system that consists of four types of units:

Main Control Module (MCM)

Cylinder Control Module (CCM)

Local Display Unit (LDU)

Safety Module (SM)

All units are mounted on the engine close to the engine sensors (Sensors on the engine are according to Wärtsilä standard) from where the system collects data. The signals received are processed and compared with the control parameters given.

Local display unit is installed in each genset engine for monitoring operational data and for local starting and stopping of genset engine.

WECS 8000 takes care of engine speed control, fuel transfers and fuel scheduling. The WECS 8000 also controls the start / stop sequences and engine safety system. If any input signal shows an abnormal value, the control system will first raise an alarm and then shutdown if the signal continues to deteriorate. All-important parameters handled by WECS, are transferred trough the UCP and to the Wärtsilä Operator Interface System (WOIS) where it is presented in graphical format.

Speed control system includes independent overspeed protection device.

Speed control actuator for gas fuel operation:

Pilot fuel injector (one/cylinder), controlled by CCM

Gas admission valve (one/cylinder), controlled by CCM

Speed control actuator for diesel fuel operation:

Electric-hydraulic actuator, make Woodward PG-EG, or equivalent, controlled by the MCM.

2.1.10 Sundries

Flywheel with fastening bolts.

Crankcase oil mist detector.

Electric operated turning device.

Safety valves in crankcase.

Driving mechanism for the engine driven pumps.

Vibration damper in free end housing, if required. The necessity of vibration damper is decided by the result of torsional vibration calculations.

2.2 FLEXIBLE COUPLING

2.2.1 Flexible coupling between engine and alternator 4

The choice of flexible coupling type/design is based on the torsional vibration calculation, and is therefore made after the configuration of engine and alternator is secured (after contract is made).

Cover for flexible coupling is included.

Bolts for connection of the flexible coupling to the engine flywheel are included.

Material for connecting the alternator to the flexible coupling is included.

2.3 ALTERNATOR

2.3.1 Marine synchronous alternator 4

2.3.1.1 Main technical characteristics

Water cooled brushless three-phase synchronous marine alternator with sleeve bearings.

Output	10250 kVA
Voltage	6600 V (to be further discussed / agreed!)
Current	932 A
Power factor	0,8

Rated speed	514 rpm
Overspeed	617 rpm
Frequency	60 Hz
Protection by enclosure	IP44
Applicable standard	IEC 60034
Marine classification	LR (or other major class society to be agreed)
Temparature rise stator / rotor	F/F
Insulation class	F
Ambient temperature	50 °C
Cooling water temperature	38 °C
Utilisation mode	Parallel operation with other gensets
Supply Type	Sinusoidal
Automatic voltage regulator	yes
Anti-condensation heater	yes
Stator winding temperature sensors	yes
Bearing temperature sensors	yes

2.3.1.2 Construction

The stator frame, core support and end shields are made of fabricated steel and welded together forming rigid structure. The construction is treated at the factory with epoxy paint finish.

The stator core is build of thin electric sheet steel laminations, which are insulated on both sides with heat-resistant inorganic resin.

The rotor consists of a shaft, a hub, and poles fixed on the hub. The shaft is machined of steel forging. The poles are manufactured of sheet steel and bolted to the hub.

All windings are completely vacuum pressure impregnated with high-quality epoxy resin. The windings are provided with very strong bracing which withstands all expected mechanical and electrical shocks and vibrations as well as chemicals.

2.3.1.3 Water cooling

The generator is cooled with a shaft mounted fans. The cooling air is circulated inside the generator through a double tube air-to-water heat exchanger. Emergency cooling without water is possible.

2.3.1.4 Sleeve bearings

The alternator has two pedestal sleeve bearings. The lubrication for bearings is taken from genset engine lubricating oil system.

2.3.1.5 Control systems

The excitation system comprises a digital electronic voltage regulator, an exciter and voltage/current transformers for feedback. The voltage regulator controls the generator output voltage, supplying the excitation current to the exciter. The exciter supplies the excitation current to the generator main poles.

2.4 GENSET ASSEMBLY

Genset is assembled on FSRU construction yard on a foundation prepared by the shipyard according to Wärtsilä instructions. Chapters 2.4.1 and 2.4.2 describe genset engine and alternator mounting on a foundation prepared by the shipyard.

2.4.1 Genset engine mounting 4

The genset engine is mounted on the foundation using anti-vibration mounts to reduce the transmission of vibrations from the generating set to the vessel structure. The anti-vibration mounts are of conical rubber type with incorporated movement limiters. Genset engine mounting materials are included in Wärtsilä scope of supply.

2.4.2 Alternator mounting 4

The alternator is mounted rigidly on the foundation. Alternator mounting materials are included in Wärtsilä scope of supply.

2.4.3 Flexible pipe connections 5

All pipe connections between genset engine and external circuits are flexible and included in Wärtsilä scope of supply. Mating flanges for all pipe connections are included.

One spare flexible connection set is included.

3. AUXILIARY SYSTEMS FOR GENERATING SETS

The auxiliary system components for gensets, which are included in Wärtsilä scope of supply, are described in this section.

3.1 FUEL GAS SYSTEM

In addition to the components listed herein, the complete fuel gas system typically also contains fuel gas supply compressors, flare system, and master gas fuel valves. These equipments/machineries are not included in Wärtsilä scope of supply.

3.1.1 Gas valve unit 4

One (1) gas valve unit for each genset engine is fitted.

Before the gas is supplied to the engine it passes through a Gas Valve Unit (GVU). GVU can be located either in the engine room, in a dedicated compartment, or on the deck area.

The GVU includes a manual shut-off valve, purging connection, actuated shut-off and ventilating valves, gas pressure transmitters/gauges, and gas temperature transmitters/gauges. GVU also includes gas pressure regulating valve and gas fuel filter. The valves of GVU are normally controlled automatically from the engine control sequence, and only for special testing the valves may be controlled manually. In these cases, the engine start is prevented.

The Gas Valve Unit has three main functions:

- Prior to gas operation of DF-engine the GVU performs a gas leakage test of the main shut-off valves in order to ensure that the valves are working properly before it enables gas supply to the engine.
- During DF-engine operation in gas operating mode the GVU controls gas feed pressure to the engine.
- At the end of gas operation of DF-engine the GVU shuts off gas supply to the engine and allows gas pipe to ventilate.

The pressure class of pipes and the other components on the gas valve unit are all PN16 or higher. Counter-flanges for external connections are included.

3.2 FUEL OIL SYSTEM

In addition to the components listed herein, the complete fuel oil system typically also contains fuel bunker tank(s), day tanks, sludge tank(s), overflow tank(s), and sludge treatment/offloading. These equipment/machinery are not included in Wärtsilä scope of supply.

3.2.1 Fuel oil feed unit 2

One (1) fuel oil feed unit is installed for each engine room feeding fuel oil circulating units of each engine in the engine room. Each fuel oil feed unit includes two (2) fuel oil feed pumps with suction strainers installed on a common skid. Normally one pump is running and the other is standby. Also counter-flanges for external connections are included.

The pumps are of screw type and fitted with integral pressure relief safety valve.

3.2.2 Fuel oil fine filter 4

One (1) duplex fuel oil fine filter unit is installed for each genset engine on the fuel oil circulating unit. It is possible to change/clean filter cartridges during engine running.

The filter unit includes draining and de-aeration valves. Also shut-off valves, differential pressure indicator and a drip pan are included.

Flow	7,5 m^3/h
Max. pressure	16 bar
Max. inlet temperature	150 ºC
Fineness, absolute	34 micron

3.2.3 Fuel oil cooler 2

One (1) fuel oil cooler is installed for each engine roomt.

The fuel oil surplus coming from the injection pumps is returned via a heat exchanger to the day tank. The heat exchanger is of water cooled type located inside the module. The necessary cooling water is taken from the genset engine LT fresh cooling water circuit.

3.3 LUBRICATING OIL SYSTEM

The engine is design with a wet sump. In addition to the components listed herein, the complete lubricating oil system typically also contains lubricating oil separators, system oil tanks, storage tank(s) and drain tank(s). These equipments/machineries are not included in Wärtsilä scope of supply.

3.3.1 Lubricating oil unit 4

One (1) lubricating oil unit is installed for each genset engine. The unit includes the following machinery/equipment installed on a common skid. Also counter-flanges for external connections are included.

3.3.1.1 Pre-lubricating oil pump

One (1) pre-lubricating oil pump is installed for each genset engine on the lubricating oil unit.

The pump is of screw type and fitted with integral pressure relief safety valve.

3.3.1.2 Lubricating oil cooler

One (1) plate type, full flow lubricating oil cooler is installed for each genset engine on the lubricating oil unit.

3.3.1.3 Lubricating oil thermostatic valve

One (1) direct acting, full flow lubricating oil thermostatic valve is installed for each genset engine on the lubricating oil unit. The thermostatic valve is equipped with manual override possibility.

3.3.1.4 Lubricating oil automatic filter

One (1) full flow, automatic self-cleaning, air turbine driven filter, including flushing oil cartridge and differential pressure indicator with alarm contact is installed for each genset engine on the lubricating oil unit.

3.3.1.5 Lubricating oil fine filter

One (1) full flow duplex lubricating oil fine filter unit is installed for each genset engine on the lubricating oil unit. It is possible to change/clean filter cartridges during engine running.

The filter unit includes draining and de-aeration valves. Also shut-off valves, differential pressure indicator and a drip pan are included.

3.3.2 Lubricating oil filling pump 1

One (1) lubricating oil filling pump with suction strainer, common for all genset engines, is supplied for filling/topping-up the engine oil sump. Counter-flanges for external connections are included.

The pump is of screw type and fitted with integral pressure relief safety valve.

Flow	17,4 m^3/h

3.3.3 Lubricating oil drain pump 1

One (1) lubricating oil drain pump with suction strainer, common for all genset engines, is supplied for emptying the engine oil sump. Counter-flanges for external connections are included.

The pump is of screw type and fitted with integral pressure relief safety valve.

Flow	17,4 m^3/h

3.4 COMPRESSED AIR SYSTEM

The compressed air system included in Wärtsilä scope of supply and described herein is contains all required main components. Typically the systems also have control air vessels and control air conditioning units.

The starting air vessels of different engine rooms should be connected with cross connection piping that is normally kept closed. In case of starting air system failure in one engine room, air can then be supplied from another after the failed component has been isolated.

3.4.1 Start air compressor units 2

Two (2) electric-driven starting air compressors are fitted on each unit. Compressors are equipped with air filter, air cooler, safety valve and pressure gauge. Each compressor has a control cubicle containing necessary start and stop automation. Counter-flanges for external connections are included.

Flow	88 m^3/h
El. motor power	19 kW
Discharge pressure	30 bar
Frequency	60 Hz
Voltage	460 V

3.4.2 Start air vessel 4

Two (2) starting air vessels are fitted in each engine room. Water is drained from the air vessel with a manual drain valve. Starting air vessels are fitted with pressure safety valves and manometers. Counter-flanges for external connections are included.

Capacity	2 m³
Discharge pressure	30 bar

3.4.3 Start air filter 4

One (1) starting air filter is fitted for each genset engine. Counter-flanges for external connections are included.

Max. working pressure	30 bar
Pressure drop	0,1 bar
Mesh size	400 micron

3.5 COOLING WATER SYSTEM

In addition to the components listed herein, the complete cooling water system typically also contains central cooler, sea water pumps, CW de-aeration vessels, expansion tanks, additive dosing tank and drain tank(s) . These drain tanks are not included in Wärtsilä scope of supply.

The genset cooling system contains two freshwater circuits, one high temperature (HT) water circuit and one low temperature (LT) circuit. The two circuits are combined outside the engine and use common expansion tank and central cooler. HT cooling water circuit temperature is controlled by adjusting amount of LT water entering in the HT circuit.

The HT-water passes through the engine HT charge air coolers, cylinder liners and cylinder heads via a thermostatic valve to central cooler. HT-water is circulated with an engine-driven pump.

The engine driven pump circulates the LT water through the charge air coolers and lubricating oil cooler to the central cooler. A thermostatic valve controls the temperature of LT circuit by adjusting the amount of LT cooling water going through the central cooler. Fuel oil and alternator are also cooled using LT cooling water.

Some components related to the cooling water system have already been described earlier in this specification. Fuel oil cooler is described in section **Error! Reference source not found.**, alternator cooler in section 2.3.1, and lubricating oil cooler in section 3.3.1.

3.5.1 LT cooling water thermostatic valve 4

One (1) LT cooling water three-way thermostatic valve is fitted for each genset engine. The LT cooling water temperature is controlled by adjusting the quantity of fresh cooling water through the central cooler with the three-way LT thermostatic valve.

The thermostatic valve is actuated by electric motor. The electric actuator motor of the thermostatic valve is controlled by an electronic three-way controller with temperature sensor. The thermostatic valve also incorporates a position feedback signal.

Counter-flanges for external connections are included.

3.5.2 HT cooling water thermostatic valve 4

One (1) HT cooling water three-way thermostatic valve is fitted for each genset engine. The HT cooling water temperature is controlled by adjusting the quantity of HT cooling water that is led out of the HT circuit and replaced by LT cooling water from LT circuit outlet.

The thermostatic valve is actuated by electric motor. The electric actuator motor of the thermostatic valve is controlled by an electronic three-way controller with temperature sensor. The thermostatic valve also incorporates a position feedback signal.

Counter-flanges for external connections are included.

3.5.3 Cooling water filling pump 1

One (1) cooling water filling pump is installed to the LNG FSRU. The cooling water filling pump is used for pumping cooling water from drain tank(s) to cooling water expansion tanks of genset engines.

Counter-flanges for external connections are included.

Flow	24 m^3/h
Delivery head	2 bar
Electric motor power	3,6 kW
Frequency	60 Hz
Voltage	440 V

3.5.4 Cooling water preheating unit 2

One (1) cooling water pre-heating unit is installed for each engine room. Standby engines are kept pre-heated in order to be ready for use and loading.

The unit includes the following machinery/equipment installed on a common skid. Also counter-flanges for external connections are included.

3.5.4.1 Cooling water pre-heating pump

Pre-heating pump circulates water in the HT cooling water circuit of the genset engine.

Flow	22 m^3/h
Electric motor power	1,1 kW
Frequency	60 Hz
Voltage	440 V

3.5.4.2 Electric cooling water pre-heater

Electric heater is used to keep HT cooling water in specified temperature while genset engine is standby.

Heater power	108 kW
Frequency	60 Hz
Voltage	440 V
Max. temperature	95 ºC
Max. pressure	10 bar

3.5.4.3 Pre-heating unit control cabinet

Control cabinet for the electric heater and pump.

3.6 EXHAUST GAS AND COMBUSTION AIR SYSTEM

The combustion air for genset engines is taken from inside the engine room through silencers and air filters installed on engine.

Exhaust is lead outside above the main deck.

3.6.1 Expansion bellows after turbocharger 4

Expansion bellows of stainless steel to be connected to the turbochargers outlets. Delivery includes counter flanges, gaskets, bolts and nuts. After each turbocharger there is a thermocouple for remote reading of the exhaust gas temperature

3.6.2 Exhaust ventilation system 4

The exhaust gas pipe of each genset is equipped with a ventilation system with a centrifugal fan, a flowswitch and a butterfly valve. The control function is provided by Wärtsilä.

3.6.3 Exhaust explosion relief valve 12

Explosion relief valves are fitted on the exhaust pipe to relief pressure in a safe manner in case of explosion.

3.6.4 Exhaust silencer 25 dB with spark arrester 4

Silencers are equipped with spark arrestor.

Average noise attenuation capacity 25 dB (A).

Vertically mounted.

3.6.5 Turbocharger cleaning device 1

Turbocharger water cleaning device for turbocharger turbine side.

3.7 ENGINE CONTROL AND MONITORING

3.7.1 Unit control panel 4

The UCP is an engine specific floor mounted cabinet, for mounting in a ventilated clean area (IP21).

Manual control of the engine is done from this panel.

The Unit Control Panel (UCP) controls the start and stop sequences and safeties of the Wärtsilä supplied engine and related auxiliaries. If any input signal shows an abnormal value, the monitoring system will first give an alarm and then shutdown if the signal continues to deteriorate. Parameters handled by the UCP are transferred to the Wärtsilä Operating Information System (WOIS). Ship automation system will receive most essential data, through Modbus and all control and important control/status are hard wired.

UCP includes the safety barriers needed for the gas regulating unit (GRU).

UCP to include redundant power converters, for both 24V DC (for control equipment and WECS) and 110V DC (for control of main fuel injection). Converter supply voltage is 220V AC and should be supplied from an UPS.

The automation system is designed for the safe, reliable, efficient and easy operation of the gensets, and their associated auxiliaries and electrical systems. The automation system allows centralized operation of the plant from the control room, with some exceptions, such as start air compressors and auxiliary units, which are provided with local control panels for independent automatic operation. The start, stop and operation mode selection of such units is only performed using the local control panels. Alarms and important measurements from the auxiliary units are connected to the automation system.

The operation, control and monitoring of the power plant is carried out via the unit control panel and an operator panel with display. The main control actions and monitoring of the DG set parameters are performed from the unit control panel. These actions include engine start up and stop, synchronization and genset loading control.

The unit control panels are mounted in the technical room or engine control room of FSRU. Each panel is equipped with a display for local monitoring of all DG set parameters.

The local control panels for auxiliary equipment are mounted on their respective units.

3.8 MOTOR CONTROL CENTER

Motor control centers (MCC), Low voltage switchboards 440 VAC, are steel-sheet enclosed cubicle-type switchgear including supplies for the motors and other apparatuses of included in Wärtsilä scope of delivery. External protection class of the low voltage switchgear is IP44. MCC includes one incoming feeder and contact signals to be routed to the UCP´s for control, monitoring and alarms.

All equipment are cabled to junction boxes for easy connection to the FSRU systems.

4. SELECTIVE CATALYTIC REDUCTION UNIT

A selective catalytic reduction unit can be installed to reduce the NOx and VOC emissions. The SCR is installed prior to waste heat recovery units. The urea is injected 3 – 5 meters prior to the SCR unit to ensure proper mixing of urea and exhaust gas. The unit is optimised to reduce emissions in gas mode.

4.1 EMISSION LEVELS

The emission reduction equipment is designed to meet exhaust gas emissions below. The fuel specifications have a significant impact on the emissions levels. The emission levels below are only valid for the fuel specified in chapter 2.1.2. The sulphur content in the liquid fuel will highly determine the SO_x emissions, which can only be specified after the final diesel specification has been reviewed.

4.1.1.1 In gas mode [1)] :

NOx	9 ppmv,dry at 15% O_2
CO	20 ppmv,dry at 15% O_2
VOC	40 ppmv,dry at 15% O_2
$PM_{10,dry}$	10 mg/m^3 dry at 15% O_2

4.1.1.2 In diesel mode [1)] :

NOx	150 ppmv,dry at 15% O_2
CO	25 ppmv,dry at 15% O_2
VOC	60 ppmv,dry at 15% O_2
$PM_{10,dry}$	21 mg/m^3 dry at 15% O_2

[1)] Values at 90% load, not valid at other loads!

4.1.1.3 Applicable measurement methods for emissions:

NO_x USA EPA Method 7E: Determination of nitrogen oxides from stationary sources (instrumental analyzer method).

VOC USA EPA Method 18: Measurement of gaseous organic compound emissions by gas chromatography. VOC is defined as Non Methane Non Ethane Hydrocarbons. Measured components are C3H8, C4H10, C5H12, C6H14, C2H4, C3H6, C4H8, C5H10 and C6H12. Formaldehyde concentration is negligible after a catalyst. If required this can be verified with method CTM-037.

$PM_{10,dry}$ USA EPA Method 17: Determination of particulate emissions from stationary sources (in-stack method)

CO USA EPA Method 10 : Determination of carbon monoxide emissions from stationary sources.

Measurement uncertainties to be evaluated by the party that carries out the measurement. The assessment of the guarantee fulfilment to be performed according to Section 6.2 of the VDI 2048 guidelines.

4.1.1.4 Typical consumption of one SCR unit in gas mode:

Urea cons.(40 wt%) at 100% MCR	19 l/h
Urea cons.(40 wt%) at 90% MCR	17 l/h
Urea cons.(40 wt%) at 75% MCR	16 l/h
Urea cons.(40 wt%) at 50% MCR	14 l/h

4.1.1.5 Typical consumption of one SCR unit in diesel mode:

Urea cons.(40 wt%) at 100% MCR	150 l/h
Urea cons.(40 wt%) at 90% MCR	133 l/h
Urea cons.(40 wt%) at 75% MCR	107 l/h
Urea cons.(40 wt%) at 50% MCR	69 l/h

4.2 SCR UNIT 4

- one charge of catalysts included

4.2.1 Reagent feeding unit 1

Including:

- One commom pump for all engines and one stand by pump

4.2.2 Reagent dosing unit 4

Including flow control dosing, check valve and instrumaentation.

4.2.3 Urea injection system 4

- including nozzles for atomizing the reducing agent

5. EXHAUST GAS WASTE HEAT RECOVERY UNIT

In this specification waste heat recovery is fitted for two engines. At the moment our proposal is that two engines are dedicated to the two boilers and the other two engines can not be utilised for waste heat recovery.

5.1 EXHAUST GAS BOILER 2

Capacity 800-1000 kW

Includes water inlet and outlet & steam headers

5.1.1 Circulating pumps 4

One stand by pump for each boiler

5.1.2 Steam drum 1

One common steam drum for the boilers

5.1.3 Control panel for WHRU unit 1

Controls the exhaust gas boiler and the auxiliary equipment for the boiler

6. PACKING AND TRANSPORTATION

6.1 PACKING

All equipment in Wärtsilä scope of supply are packed and/or protected seaworthy for transportation.

Genset engines and alternators are covered with tarpaulins.

6.2 TRANSPORTATION

The equipment is supplied ex-works in Europe unless otherwise agreed in contract.

Lifting tool for lifting genset engines during transportation. The lifting tool supplied with the engine shall be returned within 8 weeks after installation. If the lifting tool is not returned Wärtsilä will invoice the cost of the lifting tool.

Transport foundation for transporting the engine. The transport foundation supplied with the engine shall be returned within 8 weeks after installation. If the transport foundation is not returned Wärtsilä will invoice the cost of the transport foundation.

7. TAG NUMBERING SYSTEM

Tag plates for equipment will be supplied by Wärtsilä.

8. DOCUMENTATION

8.1 INSTALLATION PLANNING INSTRUCTIONS

Wärtsilä shall prepare and provide the Buyer with three (3) sets of Installation Planning Instruction (IPI), which includes drawings and instructions in English necessary for the Buyer's installation work of the equipment included in Wärtsilä scope of supply.

It shall be mutually understood, that the delivery schedule for the IPI-files (or relevant parts of the IPI-files) is dependent upon supply of all technical and associated data / information / drawings from the Buyer (or third party equipment supplier / shipyard) in order to enable preparation of the above-mentioned IPI-files, and both schedules shall be defined separately in the Contract.

8.2 TORSIONAL VIBRATION CALCULATION

It shall also be mutually understood, that the Buyer shall prepare and provide Classification Society (CS) with all drawings subject to CS approval. Wärtsilä in their turn shall prepare and provide CS with Torsional Vibration Calculations (TVC) for the shaft system.

8.3 HAND-OVER DOCUMENTATION

Wärtsilä shall prepare and provide the Buyer with three (3) sets of Operation and Maintenance (O & M) Manuals and Spare Parts Catalogues in English covering the equipment included in Wärtsilä scope of supply. These documents are provided in A4 size binders.

One record book of engine parameters (including EIAPP statement of compliance) per engine is delivered.

The delivery schedule for these O & M manuals, Spare Parts catalogues and final project documentation (including certificates, etc.), shall be defined separately in the Contract.

9. OPTIONS

9.1 INSTALLATION AND START-UP SUPPORT

Wärtsilä shall provide installation and commissioning support according to separate mutual agreement. The commissioning support will be charged in accordance with Wärtsilä service charge price list (will be submitted upon request).

It is mutually understood that Wärtsilä personnel shall only be employed for supervising, consulting and advising purposes, as well as checking the installation prior to start-up, in connection with the commissioning work. This can include a possible sea trial of the vessel.

The Buyer shall notify Wärtsilä at least two (2) weeks before the mobilisation is required and a commissioning kick-off meeting shall be held prior to starting of the commissioning activities in order to mutually agree upon the commissioning plan for the Wärtsilä scope of supply.

Technical documentation in form of drawings, specification etc. that may be necessary for the successful completion of the commissioning work shall be supplied by the Buyer.

The required time shall be reserved for checking the installation before starting up the engines. During this installation check, no other major jobs shall be allowed in the engine room and no welding or spray painting may be done above or next to the engines, unless agreed in writing with Wärtsilä representative.

It shall also be mutually understood, that Wärtsilä personnel is to take no responsibility for the engine room and other equipment in connection with sea trials. The chief engineer, or equivalent, responsible for the vessel shall be present at the expense and initiative of the Buyer.

9.2 SPARE PARTS

9.2.1 Spare parts for start-up and commissioning

Spare parts required for start-up and commissioning of the machinery in Wärtsilä scope of supply. A separate offer will be submitted on request.

9.2.2 Consumable spare parts

Consumable spare parts for two (2) years operation of the LNG FSRU power plant based on 7800 annual running hours per genset using gas as fuel. A separate offer will be submitted on request.

9.2.3 Capital spare parts

Capital spare parts include some of the most critical machinery components guaranteeing shortest possible lead time of these components in case of failure. A separate offer will be submitted on request.

9.3 TOOLS FOR GENSETS AND AUXILIARY EQUIPMENT

Special hand tools and hydraulic tightening tools required for maintenance of machinery in Wärtsilä scope of supply. A separate offer will be submitted on request.

9.4 OPERATION & MAINTENANCE AGREEMENT

Under a special contract Wärtsilä can offer spare parts, spare parts service exchange, supervisor or service crew for the FSRU. Wärtsilä can even take responsibility of operating the power plant with guaranteed availability. Scope of operation and maintenance agreement has to be mutually agreed and separate offer will be submitted on request.